Regional Distribution of Contaminants in Whole Fish From Streams and Rivers in the Mid-Atlantic States

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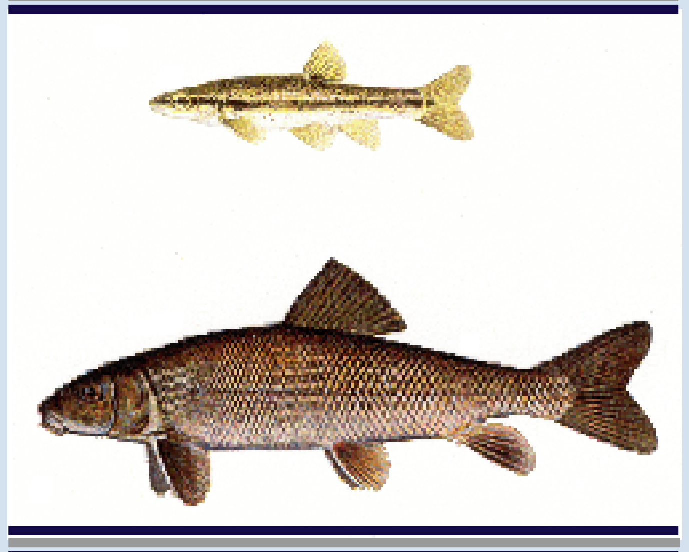
ABSTRACT

In the summers of 1997 and 1998, the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) conducted a probabilistic monitoring and assessment project in the Mid-Atlantic Region (MAR) of the eastern United States. One of the indicators used was whole-body contamination of fish in wadeable and non-wadeable streams. In an earlier study (1993/1994) of wadeable streams in the MAR we found that fish assemblages were dominated by small, short-lived adult fishes (e.g., minnows, darters, stonerollers) that were more widely distributed and abundant than large fishes typically chosen for tissue-contaminant studies (e.g., trout, black bass, sunfish, common carp). The objectives of both the 1993/1994 and 1997/1998 studies were to 1) evaluate a multi-fish-species approach for contaminant sampling; 2) compare the extent of exposure of stream ecosystems to contaminants of concern using small adult fish and large adult fish; and 3) compare regional estimates of wildlife exposure to wildlife toxicity benchmarks using small adult fish and large adult fish. In the 1997/1998 study, a total of 240 sites (116 in 1997 and 124 in 1998) were assessed for fish contamination. Whole-fish homogenates were analyzed for 11 pesticides, 14 inorganic analytes (including mercury), and 19 PCB congeners. All samples analyzed had mercury levels above the detection limit and most whole-body fish-mercury concentrations were above a wildlife risk value (kingfisher) of 30 g/kg. Most (>95%) of the samples analyzed contained detectable levels of total PCBs and DDT. Regional estimates of these contaminants indicate a broad geographical distribution of mercury and several persistent bioaccumulative organic chemicals.



INTRODUCTION

When coupled with a study design such as EMAP, the fish tissue contaminants can be used to:

1)Estimate regional risks of consumption to predators of fish, either wildlife or human;

2)As an indicator of Stream condition due to the presence and magnitude of contaminates; and

3) To track how this risk changes with time in a region.

For streams surveys, the smaller forage fish species have been shown to have a number of potential advantages over the larger sports fish species that are typically collected in stream or lake surveys(Lazorchak, et.al 2003):

1) In streams, they were found to be more ubiquitous than the larger fish species, and present in greater numbers at most sites. They were found at a greater number of sites, and more individuals were available per site to composite (we were able to collect of 20 to 200 small fish as opposed to 3 to 5 large fish). More individuals per site gave a more representative sample of the contaminant exposure in that stream section.

MATERIALS AND METHODS

Study area and sampling design

The Mid-Atlantic Integrated Assessment (MAIA) study region in the eastern United States is 204,486 km2 in area and extends from the Atlantic Ocean to the Ohio River, and from the headwaters of the Susquehanna River basin in New York to the Roanoke/Chowan River basin in North Carolina (Figure 1). Stream/river sample sites were selected using a randomized sampling design with a systematic spatial component. The sample frame was based on all stream/river traces ("blue lines") present on the digital 1:100,000 scale U.S. Geological Survey (USGS) topographic maps that were incorporated into U.S. EPA's River Reach File (Version 3, www.epa.gov/OST/BASINS/metadata?rf3a.htm). Small first-order streams make up 56% of the stream length in the region whereas boatable rivers make up only 5% of the total length. We used variable sample probabilities based on stream Strahler order to more equitably spread the sample sites among all size classes so we could make subpopulation estimates for conditions in small vs. medium vs. large systems. Each sample site had a weighting factor (calculated as the inverse of the selection probability) so that inference to the entire population of streams/rivers in the study area could be made using the sample data . In all, we sampled 291 sites representative of 218,600 km of stream/river length in the region. It was not possible to collect fish tissue data at all sample sites; tissue data were collected from 219 different sites representative of 201,590 km of wadeable and boatable MAIA streams.

Fish Species Selection

Using regional ichthyological references we considered species or species groups for whole fish tissue sampling that, based on their native range, we expected to be widely-distributed, abundant and representative of communities present in small, wadeable streams in the MAIA. We established two categories of fishes: one characterized by small (typically <100mm), short-lived (2-5 year) adults; and one that had large (typically >150mm) and long-lived (>3 years) adults. These size criteria were chosen from regional ichthyology references and are meant to serve as surrogates for age (since aging fish in the field is not practical). Our expectations were that fish belonging to species that achieve large sizes as adults would exceed minimum size (SL) criteria by a particular age as reported in ichthyology references. The small species group consisted of blacknose dace (*Rhinichthys atratulus*), any similar species (*Rhinichthys*, *Phoxinus*, or *Clinostomus* spp.), creek chub or fallfish (*Semotilus* spp.), slimy or mottled sculpin (*Cottus* spp.), central stoneroller (*Campostoma anomalum*), a darter species (*Percidae*, *Etheostoma* spp., *Percina* spp. etc.), or a shiner species (*Cyprinidae*, *Notropis* spp.). Large species included white sucker (*Catostomus commersoni*), northern hogsucker (*Hypentelium nigricans*), a black bass (*Centrarchidae*, *Micropterus* spp.), a trout species (*Salmonidae*), a sunfish species (*Centrarchidae*, *Lepomis* spp.), or common carp (*Cyprinus carpio*). We prioritized species lists based on the probability that a species would be captured in sufficient numbers to provide a sample for analysis of whole fish tissue concentrations. (Lazorchak, et. al., 2003)

Field Collection of Samples

Streams were sampled during a 12-week period from April to July, corresponding to spring low flow conditions. Fish were collected by electroshocking according to standard time (45-180 min) and distance (150-500 m, equivalent to 40X the mean wetted channel width) criteria using pulsed direct current (DC) backpack electrofishing equipment supplemented by seining (EMAP, 1997 & 2002). Samples for whole fish homogenate analyses of small and large fishes were obtained from the fish collections where sufficient numbers of individuals and sample weights were available. For small fish species, 20 to 200 individuals were composited to obtain a sample weight between 50 and 400g. A minimum of three individuals of a large species was kept for whole fish analysis. Field crews were instructed to save individuals of similar length. As a general rule, the total length of the smallest individual included in the composite was no less than 75% of the total length of the largest individual. Composite samples of small fish species were wrapped in aluminum foil in the field. Large fish species were wrapped individually. Samples were double-bagged in labeled plastic bags and sealed with tape. Samples were placed on dry ice or in a portable freezer as soon as possible after collection and kept frozen until they were shipped via overnight express mail.

Laboratory Analyses

1997 and 1998 fish tissue samples were analyzed through a U.S. EPA on-site contract in Cincinnati. The Cincinnati laboratory followed the EMAP-Surface Waters Quality Assurance Project Plan for EMAP-Surface Waters and procedures found in Yeardley et al. [2]. The approach taken was one that is performance-based and does not specify a single, standardized method for laboratory analysis of its target analytes. The analytical lab chose any method, as long as the required Quality Assurance/Quality Control (QA/QC) elements were present and the QC limits were met. Some of the key elements of this QA/QC are: Control Chart that shows proof of ability to consistently meet SRM warning limits of 80-120% for organics, 90-110% for inorganics and control limits of 70 - 130% for organics and 85-115% for inorganics. For Spiked Matrix recoveries > 50% was set as a warning limit.

DERIVATION OF WILDLIFE VALUES

Wildlife values (WVs) were derived for chlordane, DDT, dieldrin, endrin, hexachlorobenzene, mercury and PCBs. A species-specific WV for each chemical was derived for belted kingfisher, river otter and mink. The methodology and assumptions used in deriving the WVs are essentially as described previously in EPA's Great Lakes Water Quality Initiative (GLWQI); the major difference being that for the current study the wildlife values are expressed as fish tissue concentrations (millgrams chemical per gram of fish tissue) Table 1 (Lazorchak, et. al. 2003).

Table 1. Contaminants evalutated in this study with detection limits and wildlife values for protection of piscivorous wildlife.

Contaminant	Detection Limits mg/kg	Wildlife Values (mg/kg fish)		
		Otter	Mink	Kingfisher
Chlordane	0.001	1.14	0.83	0.0045
DDT & metabolites	0.001	0.49	0.36	0.02
Dieldrin	0.001	0.03	0.02	0.36
Mercury	0.01	0.10	0.07	0.03
PCBs[a]	0.001	0.18	0.13	0.44

[a] Polychlorinated Biphenyls

Figure 1 Map of MAIA 1997/1998 Study

Map Provided by: Suzanne M. Pierson, Indus Corporation, Corvallis, OR

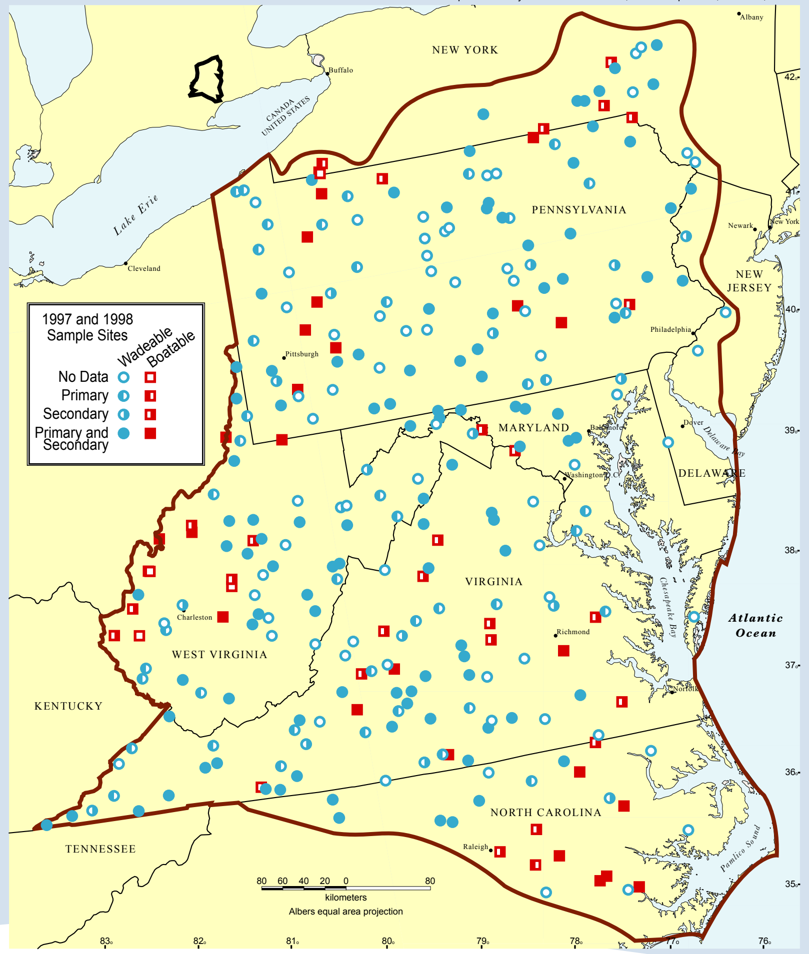


Figure 2. Whole Fish Tissue Concentrations above Detection Limits in Small vs Large Fish as percentage of Total km assessed (148,577 km) for Tissue samples by Stream Order

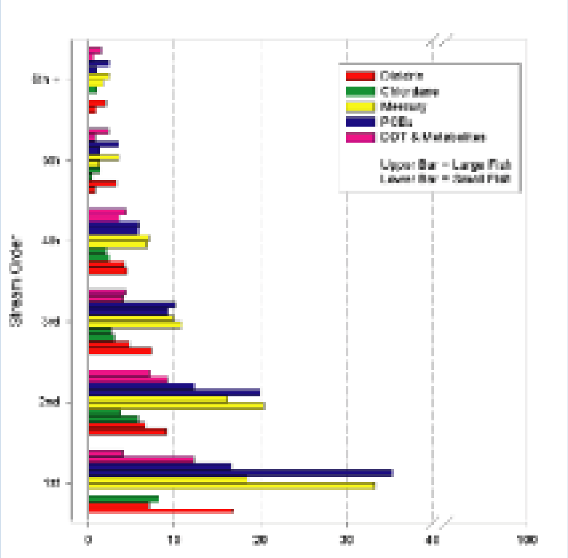


Table 2. Summary of the Number of Sites and the Extent of km of all sites visited in 1997/1998, of the total how many were small fish were collected, the most prevalent group of small fish, sites where large fish were collected and the most prevalent large fish groups.

Resource	Number of Sites	Extent (km)
Total MAIA Sample	279	201,590
Sites with Small Fish	165	117,415
Cyprinids	133	107,075
Other Small Fish	30	9,735
Sites with Large Fish	164	87,532
Catostomids	92	52,718
Bass	64	22,930
Other Large Fish	7	11,794.7
Sites with No Data	72	70,042

Table 3. Summary of the Percent of Total Assessed Stream Length in the MAIA Study Area (134,444 km) for which Tissue Concentrations in Small Adult Fish Exceed Detection Limits and Wildlife Values.

	Exceeds Detection Limit	Exceeds Kingfisher Wildlife Value	Exceeds Mink Wildlife Value	Exceeds Otter Wildlife Value
Chlordane	46.6	1.1	0	0
Dieldrin	51.3	0	0.73	0.13
DDT & Metabolites	33.6	0	0	0
PCBs	93.1	0.07	4.3	1.9
Mercury	94.6	90.44	46.7	94.6

Table 4. Summary of the Percent of Total Assessed Stream Length in the MAIA Study Area (94,933 km) for which Tissue Concentrations in Large Adult Fish Exceed Detection Limits and Wildlife Values.

	Exceeds Detection Limit	Exceeds Kingfisher Wildlife Value	Exceeds Mink Wildlife Value	Exceeds Otter Wildlife Value
Chlordane	36.4	0	0	0
Dieldrin	44.7	0	2.3	0.1
DDT & Metabolites	37.3	0.9	0	0
PCBs	87.3	0	6.7	3.5
Mercury	97.6	95.4	59.5	38.3

Table 5. Summary of Number of Sites and Stream Length (km) Assessed by Stream Order Showing Percent of Stream Length Assessed (148577 km) for Tissue Levels that Exceed Detection Limits in Small Adult Fish.

Primaries	# of sites	Length (km)	Dieldrin	Chlordane	Hg	PCB	DDT
1st	21	53883.00	16.78	8.14	33.21	35.25	12.21
2nd	46	31665.10	9.11	5.76	20.30	19.96	9.15
3rd	38	17239.60	7.30	3.05	10.79	9.35	4.07
4th	28	10115.50	4.47	2.37	6.81	5.81	3.55
5th	12	1899.10	0.76	0.34	1.28	1.22	0.74
6th through 8th	20	2612.38	0.90	0.00	1.76	1.02	0.60

Table 6. Summary of Number of Sites and Stream Length (km) Assessed by Stream Order Showing Percent of Stream Length Assessed (148577 km) for Tissue Levels that Exceed Detection Limits in Large Adult Fish.

Primaries	# of sites	Length (km)	Dieldrin	Chlordane	Hg	PCB	DDT
1st	10	28953.80	6.95	0.00	18.47	16.61	4.07
2nd	35	24425.20	6.65	3.73	16.10	12.29	7.16
3rd	32	15015.00	4.77	2.64	9.90	10.11	4.42
4th	30	10324.90	4.11	2.03	3.59	5.93	4.39
5th	32	5340.70	3.23	1.36	3.59	3.53	2.27
6th through 8th	25	7472.79	1.94	1.02	2.34	2.34	1.50

CONCLUSIONS:

1) As in the1993/1994 EMAP study, small adult (primary) fish collected in 1997/1998 were more prevalent in wadeable streams than larger adult fish (Tables 2, 5 and 6)

2) Many of the 5 contaminants analyzed in this study are detected at a higher percentage of stream km in small wadeable streams (1st - 3rd) than in larger wadeable (5th) and Non-Wadeable streams (6th and higher). (Figure 1)

3) Mercury and PCBs, were detected in 50% or greater of the stream miles assessed in both small and large adult fish. This may indicate a widespread presence of these two persistent bioaccumulative chemicals.(Tables 3 and 4)

4) Significant exposure to mercury may occur for piscivorous wildlife consuming either small or large fish, since 23.5% to 73.7% of total stream miles assessed had fish tissue concentrations exceeding the mammalian and avian mercury wildlife values.

5) Small fish detected dieldrin, chlordane, Hg, and PCBs at higher percentages of the sites assessed in 1st through 4th order streams than large adult fish. While Large adult fish detected dieldrin, chlordane, Hg, and PCBs at higher percentages of the sites assessed in 5th through 8th order streams. (Tables 5 and 6).

6) The results indicate that piscivorous wildlife that feed upon fish in 1st - 3rd order streams may experience higher exposures and greater risk because contaminants were more prevalent and exceeded wildlife values in a greater percentage of the stream km in these streams than in larger (5th order and greater) streams.

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